Space Weather Technical Forecast

Issued on Monday, 01 January 2024 at 13:36 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

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Space Weather Forecast Headline: Persistent chance of M-flares, and a slight chance of further X-flares. Chance of G1-G2 Minor-Moderate storms associated with glancing CME influence 2nd Jan.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: High with a single X5.0 flare from AR3536 at 31/2155 UTC. There are three numbered sunspots and two small unnumbered spots on the visible disk. The most notable region is AR3536 in the east, potentially returning ex-AR3514. This is a moderately sized region, with a recent trailer portion emergence around the limb. The leader potion has a complex north/south alignment, leading to significant magnetic complexity and is now classed as a beta-gamma. The other regions remain smaller and simpler, with the larger regions either stable or decaying.

The X5.0 flare produced a complex CME with a fast central portion and a broad shockwave visible in nearly all output. Analysis of this CME is complicated by a lack of imagery, most notably STEREO, which reduces confidence, but a glancing blow looks to be possible into day 2 (02 Jan).There were several other CME's observed through the period, with a number being analysed as likely missing Earth and no significant Earth directed components identified.

Solar Wind / Geomagnetic Activity: Background wind speeds were observed with a flat trend until around 01/1000 UTC, averaging around 310 km/s before increasing to 360-370 km/s to end the period signaling the likely arrival of the HSS associated with CH86. Density was generally around or below average but with a slowly rising trend, peaking around 01/1000 UTC at around 14ppcc. Interplanetary Magnetic Field (IMF), Bt, was generally weak between 0-8nT, becoming briefly moderate around 01/1000 UTC. The north-south component, Bz, was weak, fluctuating between +4/-5nT. Phi angle was generally negative (towards the Sun). Geomagnetic activity remained Quiet (Kp 0-1).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was mostly at background, though a minor response post X5.0 flare was observed and ongoing. GOES16 high energy (greater than 2MeV) electron flux ranged was mainly at background. The 24-hour fluence was below Active throughout. The 01/0000 UTC observation was 4.18e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Region AR3536 on the eastern limb dominates the flare risk during the forecast period. Generally Moderate activity is expected, with further isolated M-flares likely and a slight chance of further X-flares.

Solar Wind / Geomagnetic Activity: Glancing influence from the large CME associated with the X5.0 flare possible into day 2 (02 Jan) and there are several weak, potentially glancing CMEs that may have a very minor influence later in the period. Slow wind conditions initially,

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with background speeds, are expected to become slightly elevated to elevated on day 1 (01 Jan) due to the onset of faster winds from CH86/-. Elevated winds are likely to persist day 2 before easing day 3 (02-03 Jan) in the absence of CME influences.

Overall mainly Quiet geomagnetic activity is expected to start, becoming Unsettled with a chance of Active intervals and a slight chance of G1 Minor storms later on day 1 (01 Jan). A chance of G1-G2 Minor to Moderate storms day 2 (02 Jan) with the potential for glancing CME arrival. This risk reducing days 3-4 (03-04 Jan), however Active intervals remain possible from any very slight CME enhancement/s that may occur.

Energetic Particles / Solar Radiation: GOES16 high energy proton flux is expected to remain below S1 storm levels, however there remains a slight chance of breaching the S1 threshold into the period, initially due to the X5 flare and each subsequent day should any further notable flares occur, most likely in association with AR3536. GOES16 high energy electron flux is likely to remain near background in the short term, but is expected to reach Moderate levels, with a chance of reaching High at diurnal peaks, from day 3 (03 Jan). The associated 24 hour fluence is expected to remain below Active through the period, but with a rising trend by the end of the period.

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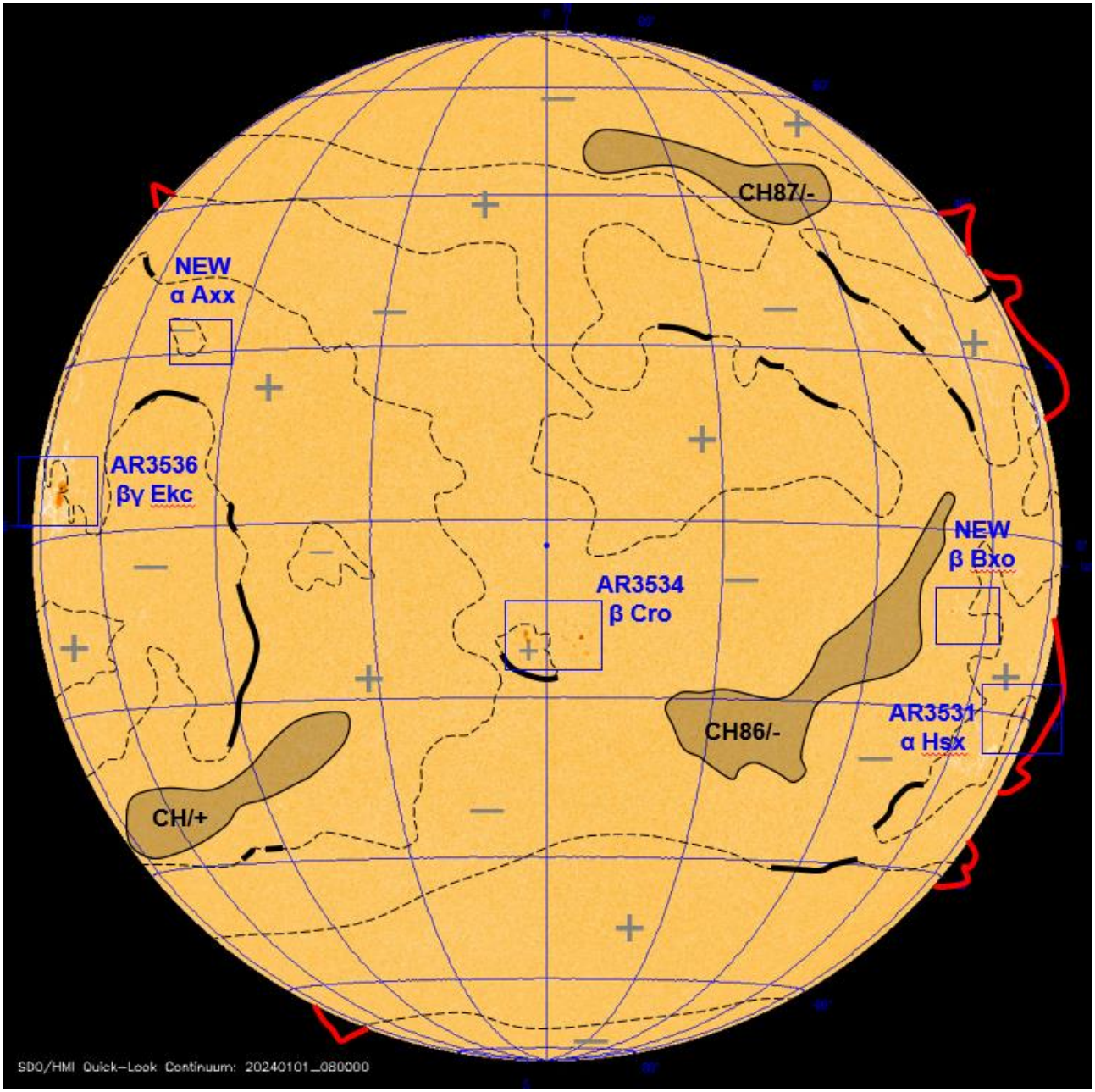
Figure 1. Solar Analysis Valid 01/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Met Office Space Weather Technical Forecast

Geomagnetic Storms:

The CME forecast is dominated by the X5.0 flare and associated CME observed from region AR3536 approximately 31/2155 UTC. This flare produced a complex CME with a fast central portion and a broad shockwave visible in nearly all output. Analysis of this CME is complicated by a lack of imagery, most notably STERO, which reduces confidence, but a glancing blow looks to be possible into day 2 (02 Jan). This expected to be largely shock however, with significant ejecta and geomagnetic response deemed unlikely for now. This CME remains under investigation and the forecast may be updated should further imagery and data become available.

Further low confidence glancing CME impacts are possible for day 2 (02 Jan) onwards from one or more recent events, these mostly faint and slow, and the already low confidence further reduced by the likely complex interaction with the larger X5.0 CME. Significant impacts look unlikely but a generally unsettled near Earth environment expected into the coming days.
Slow wind conditions initially, with background speeds, are expected to become slightly elevated to elevated through day 1 (01 Jan) due to the likely onset of fast winds from CH86/-, in-line with persistence and MOSWOC Enlil. This is a relatively narrow feature compared with the last rotation, at least along its equatorial section, when solar wind speeds of 500-600km/s were observed and geomagnetic activity peaked at Unsettled. Similar speeds are expected on this occasion, however, as a persistent feature there is the chance for Active intervals and slight chance of G1/Minor Storms. Elevated winds are likely to persist day 2 before easing day 3 (02-03 Jan) in the absence of CME influence.

Overall mainly Quiet geomagnetic activity is expected to start, becoming Unsettled with a chance of Active intervals and a slight chance of G1 Minor storms later on day 1 (01 Jan). A chance of G1-G2 Minor to Moderate storms day 2 (02 Jan) with the potential for glancing CME arrival. This risk reducing days 3-4 (03-04 Jan), however Active intervals remain possible from any very slight CME enhancement/s that may occur.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	50	20	10
Strong	G3	No	1	5	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
01/0025	Partial Halo	AR3536	E Limb	1500 km/s	02/1200 UTC +- 12hr	Low confidence, generally shock expected.

Radio Blackouts - X-Ray Flares:

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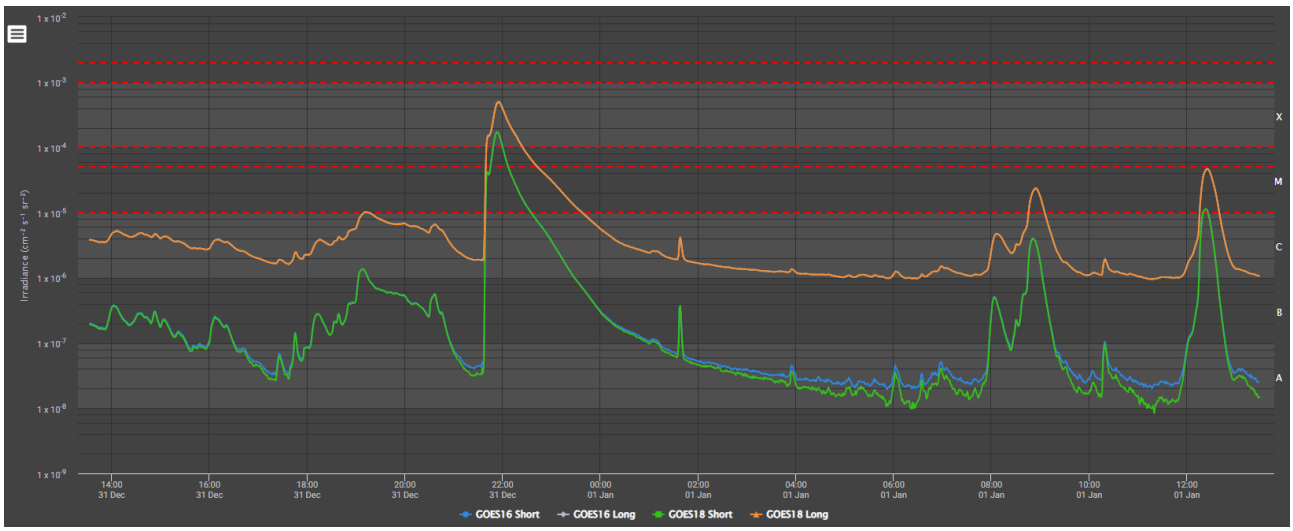
Solar activity is High due to the X5.0 flare at 31/2155 UTC from region AR3536 (perhaps ex-AR3514) on the eastern limb, and the flare risk remains dominated by the region during the forecast period. Generally Moderate activity is expected, with further M-flares likely and a slight chance of further isolated X-flares. The risk of further X-Class flares may be reduced somewhat pending further analysis as AR3536 continues to rotate towards a less oblique viewing angle. Signs of some simplification have been observed, perhaps following the recent significant flare, with a delta spot no longer visible. The spot remains magnetically complex however and further complexity may get emerge given the only recent emergence of the likely trailing portion.
The other regions currently on the visible disk remain simpler, with the larger regions either stable or decaying.

Far-side seismic products support the continued arrival of a notable active region or regions in the next 24 hours, which would correspond to the return a cluster of sunspots that included ex-AR3514, now perhaps AR3536, the source of the last X-flare on 14 Dec. The most recent Mars Perseverance rover image of the Sun, while from just over a week ago (22 Dec), showed this cluster of spots persisting on the far-side.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**R1-R2 M Class**	Yes	60	60	60	60
Very Active	**R3 to R5 X Class**	Yes	20	20	20	20

Figure 2: Latest 24hr GOES 16/18 X-ray trace, showing recent activity associated with AR3536.



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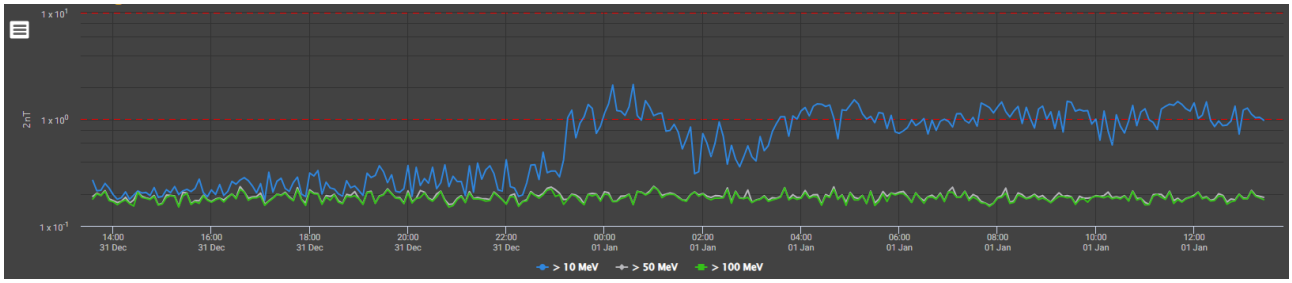
Solar Radiation Storms - (High Energy Protons):
GOES16 high energy (greater than 10MeV) proton flux is still currently responding to the X5.0 flare from New Year's Eve. Proton flux expected to peak below the S1 storm level, however there remains a slight chance of breaching the S1 threshold into the period, initially due to the X5 flare and each subsequent day should any further notable flares occur, most likely in association with AR3536.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	20	20	20	20
Very Active	**≥ S3 ***	No	1	1	1	1

* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)

Figure 3: Latest 24hr Proton flux trace, showing ongoing impact of X5.0 flare.



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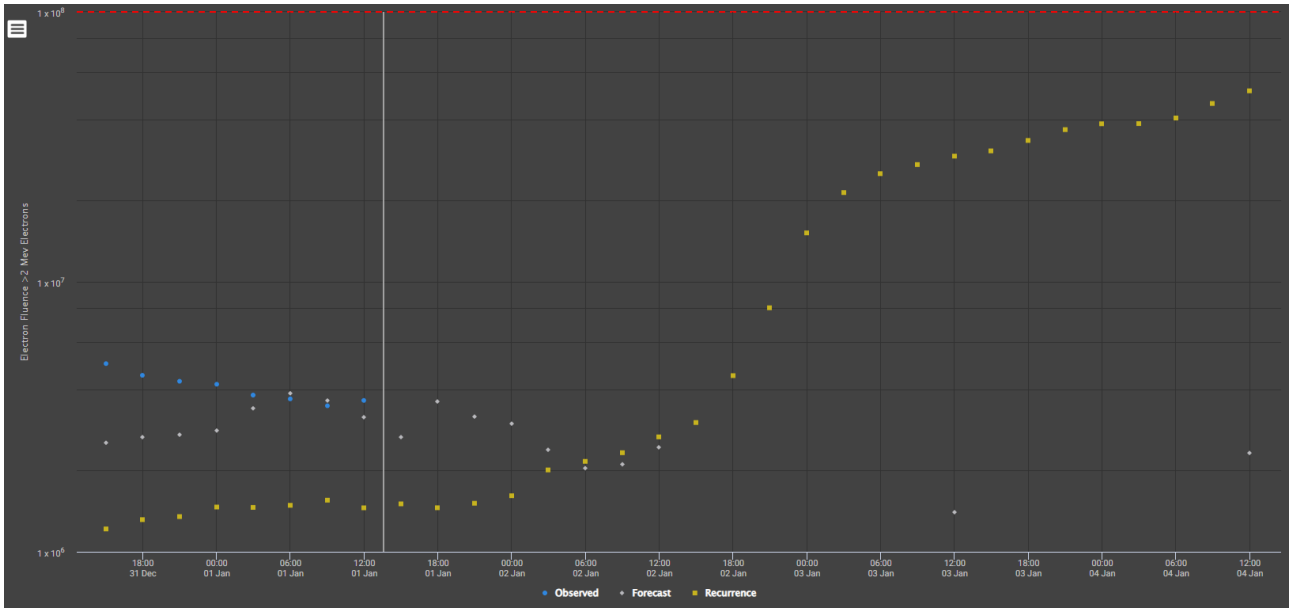
High Energy Electrons Event (≥ 2MeV):
High energy electron flux (greater than 2MeV) has seen diurnal fluctuations between background and moderate. Flux is likely to drop out to mainly background with the onset of the fast wind of CH86, before increasing to Moderate from day 3 (03 Jan) with an increasing chance of peaking at High by day 4 (04 Jan).

Electron fluence is expected to remain well below the Active (1e8 integrated pfu) threshold, but likely with a gradually increasing trend from day 3 (02 Jan) as a result of the fast wind onset. This is in line with REFM which is currently giving good guidance.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	15
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 4: Latest MOSWOC REFM model output.



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